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MICHIGAN TECH

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Health
Engineered Materials
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Adrienne Minerick



Leonard J. Bohmann



Wayne D. Pennington

Letter from the Deans

Research and discovery are the basis for new technologies and skills that will one day become integral parts of our daily lives. They deliver competitive advantages to our companies, translating into job growth and a higher standard of living for our society. The ingenuity and problem solving involved in research yields new avenues for growth, and provides creative, sustainable solutions to global challenges. These pages contain just a small subset of the exceptional engineering research conducted at Michigan Tech.

The people behind this critical quest for knowledge share a common trait—they persevere through the many setbacks of their systematic search (and repeated search, i.e. research). They first work to understand the governing laws of nature and then harness them to achieve the desired benefits. Teams of faculty, staff, and students work in concert to expand humanity's body of knowledge, to apply that knowledge to engineer solutions, and finally transfer that knowledge freely to others via publications, public outreach, patents, or direct entrepreneurship.

Michigan Tech's research environment and alignment with industry is unique. Interdisciplinary collaborations are the norm, which enable a cross-pollination of ideas and the sharing of resources that enable innovative new solutions. The close integration of experiential learning with research develops research students with practical skills immediately ready to translate knowledge into practice.

We hope you enjoy the Michigan Tech Engineering Research 2017 featured projects, which will be transforming lives in five to ten years. As always, please reach out to us with your thoughts and ideas.

A handwritten signature in cursive script, reading "Adrienne Minerick".

Adrienne Minerick
Associate Dean for Research and Innovation

A handwritten signature in cursive script, reading "Leonard J. Bohmann".

Leonard J. Bohmann
Associate Dean for Academic Affairs

A handwritten signature in cursive script, reading "Wayne D. Pennington".

Wayne D. Pennington
Dean

On the cover: PhD students Donna Fard, Brian Page, and Anthony Pinar launch the ROUGHIE, an underwater research glider. Their advisor, Nina Mahmoudian, is featured on page 22.

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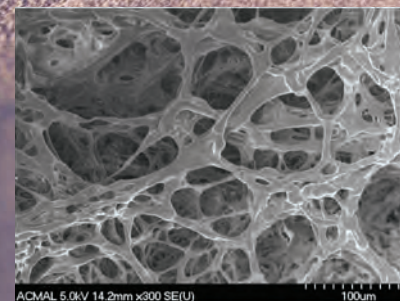
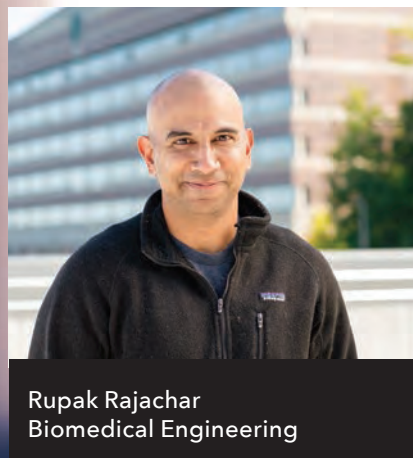
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2017 NSF CAREER Award

Contact Us

College of Engineering

Michigan Technological University
712 Minerals & Materials Engineering Building
1400 Townsend Drive
Houghton, MI 49931-1295
Telephone: 906-487-2005
Email: engineering@mtu.edu
mtu.edu/engineering



SEM image of the
fibrinogen-based
hydrogel

Accelerated healing

Understanding physical and chemical cues in tissue repair

Made of fibrous connective tissue, tendons attach muscles to bones in the body, transferring force when muscles contract. But tendons are especially prone to tearing. Achilles tendinitis, one of the most common and painful sports injuries, can take months to heal, and injury often recurs.

Rupak Rajachar is developing a minimally-invasive, injectable hydrogel that can greatly reduce the time it takes for tendon fibers to heal, and heal well.

"To cells in the body, a wound must seem as if a bomb has gone off," says Rajachar. His novel hydrogel formulation allows tendon tissue to recover organization by restoring the initial cues cells need in order to function. "No wound can go from injured to healed overnight," he adds. "There is a process."

Rajachar and his research team seek to better understand that process, looking at both normal and injured tissue to study cell behavior, both in vitro and in vivo with mouse models. The hydrogel they have created combines the synthetic—polyethylene glycol (PEG), and the natural—fibrinogen.

"Cells recognize and like to attach to fibrinogen," Rajachar explains. "It's part of the natural wound healing process. It breaks down into products known to calm inflammation in a wound, as well as products that are known to promote new vessel formation. When it comes to healing, routine is better; the familiar is better," he says.

The team's base hydrogel has the capacity to be a therapeutic carrier, too. One formulation delivers low levels of nitric oxide (NO) to cells, a substance that improves wound healing, particularly in tendons. They combine NO and other active molecules and cells with the hydrogel, testing numerous formulations. "We add them, then image the gel to see if cells are thriving. The process takes place at room temperature, mixed on a lab bench."

Two commonly prescribed, simple therapies—range of motion exercises that provide mechanical stimulation, and local application of cold/heat—activate NO in the hydrogel, boosting its effectiveness.

"Even a single injection of the PEG-fibrinogen-NO hydrogel could accelerate healing in tendon fibers," says Rajachar. "Tendon tissues have a simple healing process that's easier to access with biomaterials," he adds. Healing skin, bone, heart, and neural tissue is far more complex. Next up: Rajachar plans to test variations of his hydrogel on skin wounds.

The healing power of seaweed

Shedding new light on alginate microgels

Using seaweed to treat wounds dates back to Roman times. Alginate extracted from kelp and other brown seaweeds are still used in wound dressings today for skin grafts, burns and other difficult wounds. Alginate forms a biocompatible and biomimetic gel when exposed to a wound. It keeps tissues moist, reduces pain and trauma during dressing changes, and speeds healing.

Microgels, another biomaterial formed from microscopic polymer filaments, has broad and powerful applications in cell analysis, cell culture, drug delivery, and materials engineering. Putting the two together to form alginate microgels could enable scientists to make important new inroads in the field of tissue engineering. But when it comes to forming microgels, the gelation process of alginate literally gets in the way.

Chang Kyoung Choi has overcome that obstacle. He uses ultraviolet (UV) light to cure microdroplets into microgels, a process known as photopolymerization. Curing the alginate microgels using UV light takes just tens of seconds. The result: alginate microgels that shrink or swell depending on their surrounding ion concentration, temperature, pH, and other external stimuli.

With his photocrosslinking method, Choi is able to control the rate that alginate microgels break down. "A tissue scaffold should degrade at a rate proportional to the formation of new tissue. Until now, uncontrolled degradation of alginate has really limited its usefulness," Choi says.

"Working in microfluidic devices, we can start applying UV light after the microfluids become steady, and turn off the light if necessary to stop the reaction," he explains. "This solves the chief problem associated with previous ionic methods of making alginate microgels. Until now, the alginate phase of flow would cure before steady state was achieved, resulting in alginate microgels that clogged the microchannel."

Choi's photocrosslinking technique also simplifies current methods of forming nonspherical alginate microgels that are better for observing objects, like cells, encapsulated inside. "Our preliminary results suggest that high intensity UV light does not reduce cell viability."

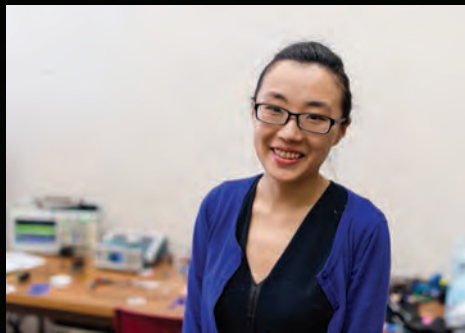
Choi and graduate student Shuo Wang use oxidized methacrylated alginate (OMA) developed by their collaborator, Eben Alsberg at Case Western Reserve University. The team fabricated the microfluidic channels for this research at the Center for Nanophase Materials Sciences at Oak Ridge National Laboratory.



Chang Kyoung Choi
Mechanical Engineering-Engineering Mechanics

Bull Kelp, a brown seaweed used to produce alginates, can grow as much as 2 feet per day.

PHOTO CREDIT: JACKIE HILDERING; WWW.THEMARINETECTIVE.COM



Ye Sarah Sun
Mechanical Engineering-Engineering
Mechanics



Sun's self-powered ECG/EEG heart monitor works despite a gap of hair, cloth or air between the user's skin and the electrodes.

Vital signs

Powering heart monitors with motion artifacts

More than 90 percent of US medical expenditures are spent on caring for patients coping with chronic diseases. Some patients with congestive heart failure, for example, wear heart monitors 24/7 amid their daily activities.

Ye Sarah Sun develops new human interfaces for heart monitoring. "There's been a real trade-off between comfort and signal accuracy, which can interfere with patient care and outcomes," she says. Sun's goal is to provide a reliable, personalized heart monitoring system that won't disturb a patient's life. "Patients need seamless monitoring while at home, and also while driving or at work," she says.

Sun has designed a wearable, self-powered electrocardiogram (ECG) heart monitor. "Physiological signals such as ECG is the gold standard for diagnosis and treatment of heart disease, but they are both weak signals," Sun explains. "When monitoring a weak signal, motion artifacts arise. Mitigating those artifacts is the greatest challenge."

Sun and her research team have discovered and tapped into the mechanism underlying the phenomenon of motion artifacts. "We not only reduce the influence of motion artifacts but also use it as a power resource," she says.

Their new energy harvesting mechanism provides relatively high power density compared with traditional thermal and piezoelectric mechanisms. Sun and her team have greatly reduced the size and weight of an ECG monitoring device compared to a traditional battery-based solution. "The entire system is very small," she says, about the size of a pack of gum.

Unlike conventional clinical heart monitoring systems, Sun's monitoring platform is able to acquire electrophysiological signals despite a gap of hair, cloth, or air between the skin and the electrodes. With no direct contact to the skin, users can avoid potential skin irritation and allergic contact dermatitis, too—something that could make long-term monitoring a lot more comfortable.

Phosphorus eaters

Using bacteria to purify iron ore

Many iron ore deposits around the world are extensive and easy to mine, but can't be used because of their high phosphorus content. Phosphorus content in steel should generally be less than 0.02 percent. Any more and steel becomes brittle and difficult to work.

Often, phosphorus is so finely disseminated through iron ore that grinding and physically separating out the phosphorus minerals is impractical.

Tim Eisele is developing communities of live bacteria to inexpensively dissolve phosphorus from iron ore, allowing a low-phosphorus iron concentrate to be produced.

"Beneficiation plant processing, which treats ore to make it more suitable for smelting, only works if the phosphorus mineral grains are bigger than a few micrometers in size," Eisele explains. "For finely dispersed phosphorus, until now, there really hasn't been a technology for removing it."

Phosphorus is critical to all living organisms. Eisele's experiments are designed so that organisms can survive only if they are carrying out phosphorus extraction. He uses phosphorus-free growth media. "We've confirmed that when there is no iron ore added to the media, there is no available phosphorus and no bacterial growth," he says.

Eisele is investigating two approaches—one using communities of aerobic organisms to specifically attack the phosphorus, and another using anaerobic organisms to chemically reduce and dissolve the iron while leaving the phosphorus behind. He obtained organisms from local sources—his own backyard, in fact—where natural conditions select for the types of organisms desired. He originally got the idea for this approach as a result of the high iron content of his home well water, which is caused by naturally occurring anaerobic iron-dissolving organisms.

Eisele cultivated anaerobic and aerobic organisms in the laboratory to fully adapt them to the ore. "We use mixed cultures of organisms that we have found to be more effective than pure cultures of a single species of organism," he explains. "The use of microorganism communities will also be more practical to implement on an industrial scale, where protecting the process from contamination by outside organisms may be impossible."

Iron ore pit mine,
Kryvyi Rih, Ukraine



Timothy Eisele
Chemical Engineering



On the right, anaerobic bacteria dissolve iron in the ferrous state. On the left, recovered electrolytic iron.

Where rubber becomes the road

Testing sustainable asphalt technologies

Over 94% of the roads in the United States are paved with asphalt mix. Each year, renovating old highways with new pavement consumes about 360 million tons of raw materials. It also generates about 60 million tons of old pavement waste and rubble.

Recycling these waste materials greatly reduces the consumption of neat, unmodified asphalt mix and lowers related environmental pollution. But blending recycled asphalt pavement (RAP) with fresh asphalt mix presents several challenges, potentially limiting its usefulness.

Not to Zhanping You. "One noticeable issue of using RAP in asphalt pavement is the relatively weaker bond between the RAP and neat asphalt, which may cause moisture susceptibility. Modifying the asphalt mix procedure and selecting the proper neat asphalt can effectively address this concern," he explains.

You tests a variety of recycled materials to improve asphalt pavement performance. Crumb rubber, made from scrap tires, is one such material. Used in asphalt, crumb rubber reduces rutting and cracks, extends life, and lowers noise levels, he says. Another plus--building one mile of road with crumb rubber uses up to 2,000 scrap tires. "Hundreds of millions of waste tires are generated in the US every year," he notes.

Adding crumb rubber to asphalt mix has its own share of problems. "When crumb rubber is blended into asphalt binder, the stiffness of the asphalt binder is increased. A higher mixing temperature is needed to preserve the flowability," You explains. He developed a warm mix technology that reduces the production temperature of asphalt mix containing crumb rubber.

"Conventional hot-mix asphalt uses a lot of energy and releases a lot of fumes. We use a foaming process at lower temperatures that requires less energy and reduces green-house gas emissions," he says.

You and his team integrate state-of-the-art rheological and accelerated-aging tests, thermodynamics, poromechanics, chemical changes, and multi-scale modeling to identify the physical and mechanical properties of foamed asphalt materials. With funding from the Michigan Department of Environmental Quality, they have constructed test sections of road in two Michigan counties to monitor field performance.

Another possible solution is asphalt derived from biomass. You's team used bio oil in asphalt and found it improved pavement performance. They're also investigating nanomaterial-modified asphalt. "Soon we'll have mix recipes to adapt to all environmental and waste supply streams," he says.



Zhanping You
Civil & Environmental Engineering

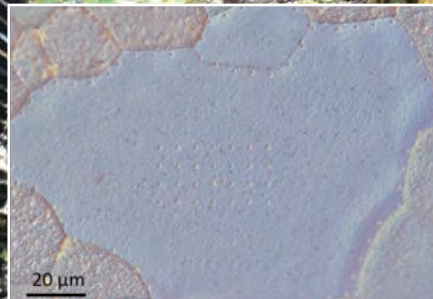


A research team led by Zhanping You tests a new, cooler way to make rubberized asphalt.

A damaged Samsung Galaxy Note 7 after its lithium battery caught fire.



Erik Herbert
Materials Science & Engineering



Surface of the polycrystalline lithium film, with over 100 residual impressions from targeted test sites

PHOTO CREDIT: SHAWN L. MINTER, VIA ASSOCIATED PRESS

The holy grail of energy storage

Solving the problems of lithium anodes

State-of-the-art mechanical characterization of pure lithium metal, performed at submicron-length scales, provides significant physical insight into critical factors that limit the performance of next generation energy storage devices.

Compared to competing technology platforms, a pure lithium anode potentially offers the highest possible level of volumetric and gravimetric energy density. Gradual loss of lithium over the cycle life of a battery prevents the full fruition of this energy technology.

Michigan Tech researcher Erik Herbert and his collaborators at Oak Ridge National Laboratory and the University of Michigan are investigating the behavior of a lithium anode accessed through, and protected by, polycrystalline superionic solid electrolytes. Their goals: Mitigate the loss of lithium; prevent dangerous side reactions; and enable safe, long-term, and high-rate cycling performance.

"We want to maintain efficient cycling of lithium in a battery over many cycles, something that's never been done before," says Herbert. "The fundamental challenge is figuring out how to maintain a coherent interface between the lithium anode and the solid electrolyte."

Defects formed in the lithium during cycling determine the stability and resistivity of the interface, Herbert says. "Once we see how that happens, it will reveal design rules necessary to successfully fabricate the solid electrolyte, and the battery packaging."

The team is launching parallel efforts to address these issues. Herbert, for his part, wants to learn exactly how lithium is consumed on a nanoscale level, in real time. "We want to know why the interface becomes increasingly resistive with cycling, how the electrolyte eventually fails, how defects in the lithium migrate, agglomerate, or anneal with further cycling or time, and whether softer electrolytes can be used without incursion of metallic lithium into the electrolyte," he says. "We also want to learn how processing and fabrication affect interface performance."

To answer these questions, Herbert conducts nanoindentation studies on vapor-deposited lithium films, various sintered solid electrolytes, and lithium films in fully functional solid-state batteries. "The data from these experiments directly enable examination of the complex coupling between lithium's microstructure, its defects, and its mechanical behavior," says Herbert.

"So far we've gained a better understanding of the mechanisms lithium utilizes to manage pressure (stress) as a function of strain, strain rate, temperature, defect structure, microstructural length scale, and in-operando cycling of the battery."

Verification and validation

Predicting uncertainties early on

Verification and validation (V&V) are essential stages in the design cycle of industrial controllers, to remove any gap between the designed and implemented controllers. Despite improvements over the years through computer modeling, the gap remains. The V&V process for a typical automotive vehicle and powertrain electronic control unit takes approximately two years, and costs several million dollars.

Mahdi Shahbakhti and his team have made significant progress to remove that gap, using system models to easily verify controller design. Their solution features an adaptive sliding mode controller (SMC) that helps the controller deal with imprecisions in the implementation of the system.

The research is funded by the National Science Foundation GOALI program, Grant Opportunities for Academic Liaison with Industry. Shahbakhti's team and fellow researchers from the University of California, Berkeley, and Toyota USA in Ann Arbor, Michigan are nearing the end of the three-year collaborative GOALI project.

"Analog-to-digital conversion (ADC) is one of the main sources of controller implementation imprecisions, mostly due to sampling and quantization," says Shahbakhti. "Our approach mitigates ADC imprecisions by first identifying them in the early stages of the controller design cycle. We developed a mechanism for real-time prediction of uncertainties due to ADC and then determined how those uncertainties propagated through the controller. Finally we incorporated those predicted uncertainties into the discrete sliding mode controller (DSMC) design."

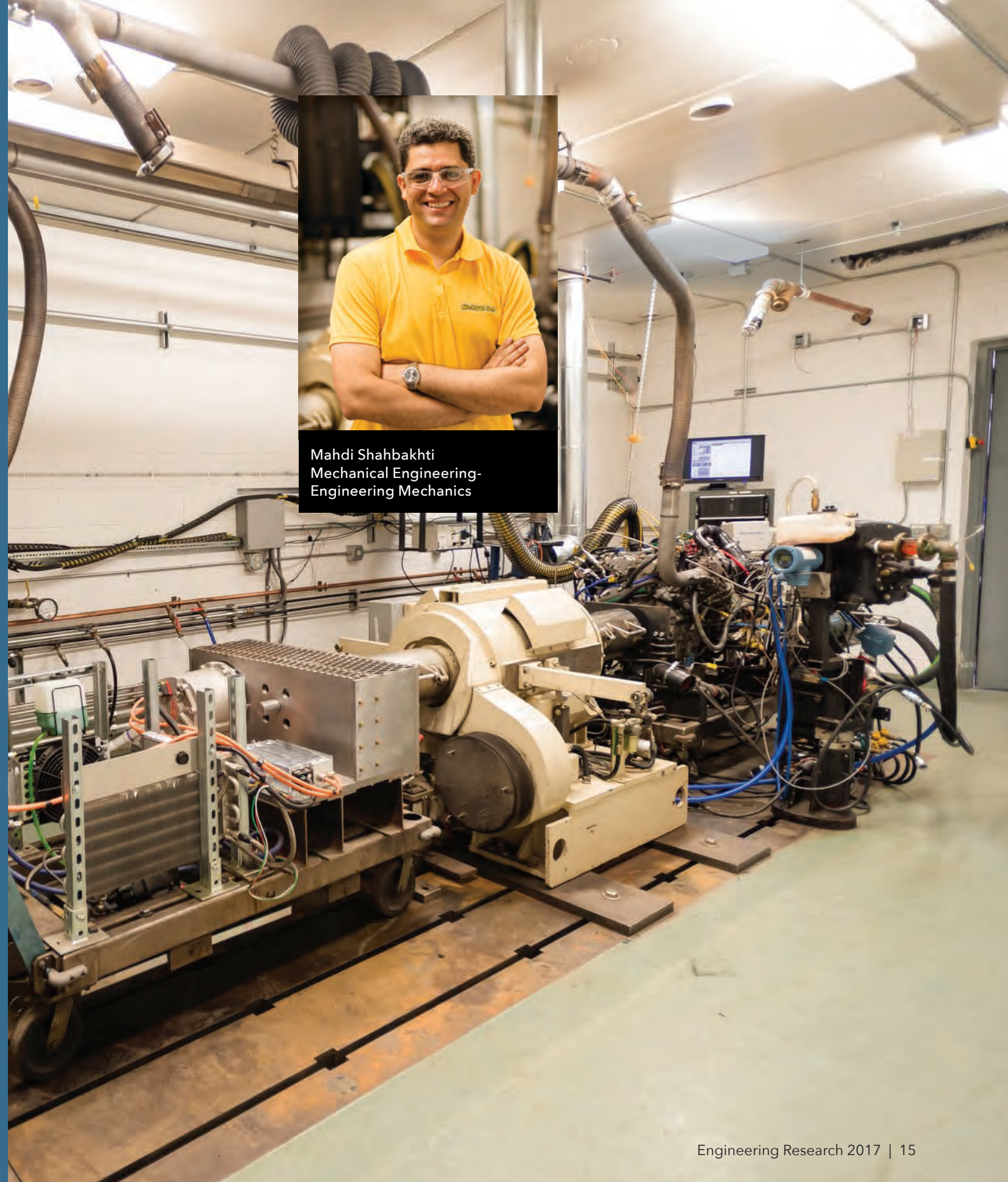
Shahbakhti's research team tested an actual electronic control unit at Michigan Tech in a real time processor-in-the-loop setup. Their approach significantly improved controller robustness to ADC imprecisions when compared to a baseline sliding controller. In a case study controlling the engine speed and air-fuel ratio of a spark ignition engine, the DSMC design with predicted uncertainty provided a 93 percent improvement compared to a baseline sliding controller.

Toyota works closely with Shahbakhti's team to integrate GOALI project results into the design cycle for its automotive controllers. The company provided team members with an initial week of training on its V&V method of industrial controllers, and also participates in online biweekly meetings.

"The concept of this project is fundamental and generic—it can be applied to any control system, but complex systems, such as those in automotive applications, will benefit most," notes Shahbakhti.



Mahdi Shahbakhti
Mechanical Engineering-
Engineering Mechanics





Sumit Paudyal
Electrical & Computer Engineering



PHOTO CREDIT: TOPHER DONAHUE, ALPINECREATIVE.COM

Demand dispatch

Balancing power in the grid in a nontraditional way

Traditionally, in the electric power grid, generation follows electric power consumption, or demand. Instantaneous fluctuation in demand is primarily matched by controlling the power output of large generators.

As renewable energy sources including solar and wind power become more predominant, generation patterns have become more random. Finding the instantaneous power balance in the grid is imperative. Demand dispatch—the precise, direct control of customer loads—makes it possible.

Sensors, smart meters, smart appliances, home energy management systems, and other smart grid technologies facilitate the realization of the demand dispatch concept. The use of demand dispatch has promising potential in the US, where it is estimated that one-fourth of the total demand for electricity could be dispatchable using smart grid technologies. Coordination and control in real-time is crucial for the successful implementation of demand dispatch on a large scale.

Sumit Paudyal and his research team are developing efficient real-time control algorithms to aggregate distributed energy resources, and coordinate them with the control of the underlying power grid infrastructure. Their goal is control dispatch distributed resources for the very same grid-level applications—frequency control, regulation, and load following—traditionally provided by expensive generators.

“We have solved the demand dispatch problem of thermostatically-controlled loads in buildings and electric vehicle loads connected to moderate size power distribution grids,” Paudyal explains.

“Since the inherent challenge of the demand dispatch process is the computational complexity arising from the real-time control and coordination of hundreds to millions of customer loads in the system, we are now taking a distributed control approach to achieve computational efficiency in practical-sized, large-scale power grids.”

Biocement

Mineralizing mine tailings with microbes to reduce blowing dust

Massive volumes of waste materials are produced annually by mining operations. A significant fraction in the form of fine-grained tailings is deposited as a slurry into large tailings disposal impoundments, subject to intense regulatory and public attention because of the hazards associated with the materials they contain.

One key hazard is air pollution from the tailings blowing as dust. Conventional approaches for controlling the dust emissions have limitations, and some have potentially negative side effects on human health and the environment.

Eric Seagren examines the use of biomediated techniques for ground improvement using microorganisms to improve the engineering properties of granular soils. "These approaches mimic and maximize the benefits of natural processes, with less impact on the environment than conventional technologies," he says.

Seagren and co-investigators Stanley Vitton and Thomas Oommen develop and test low-impact bio-geoengineering practices for stabilizing mine tailings to mitigate dust emissions. One potential approach is biocementation. "Numerous examples of microbially mediated mineralization in the natural soil environment have been documented," Seagren says. "These reactions result in relatively insoluble compounds that contribute to soil cementation."

One of these natural processes is microbially induced calcium carbonate precipitation (MICP). "It's an ubiquitous process that plays an important cementation role in natural systems, including soils, sediments, and minerals," adds Seagren.

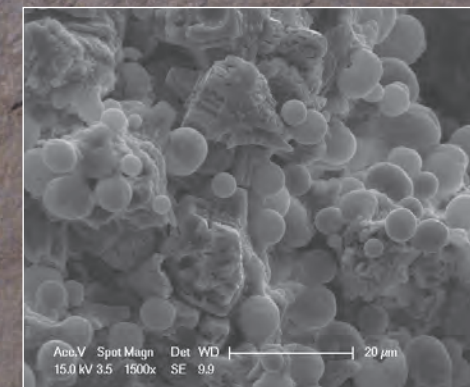
The team applied MICP to mine tailings via promotion of urea hydrolysis. "Ureolysis creates an alkaline environment that is favorable for calcite precipitation," explains Seagren. "Bacterial cell surfaces serve as nucleation sites where calcium carbonate precipitates form on the cells."

The team also developed analytical tools for monitoring treatment of the tailings via ureolysis, to confirm the formation of a surface crust of calcium carbonate and measure its impact on cementation strength.

"Interestingly, crust formation was demonstrated with samples inoculated with pure urea-degrading cultures, as well as with native microorganisms," says Seagren. "Our next step is to determine whether or not the strength increase translates into a reduction of dust emissions."



Eric Seagren
Civil & Environmental Engineering



SEM image
of microbially induced
calcium carbonate

Tailings slurry from
a copper mine in
Sabah, Borneo

Coal-fired power plant
on the Navajo Nation
near Page, Arizona



Shiliang Wu
Geological & Mining
Engineering & Sciences, and
Civil & Environmental Engineering

What's in the air?

Understanding long-range transport of atmospheric arsenic

If you'd been living in London in December 1952, you'd probably remember what air pollution can do—in just a couple of weeks, a smog event killed thousands of people. Today, photos of air pollution in China and India flood the Internet. Air pollution remains a significant challenge for the sustainability of our society, with detrimental effects on humans, animals, crops, and the ecosystem as a whole.

Once emitted into the atmosphere, many air pollutants are transported long distances, going through a series of chemical reactions before falling back to the Earth's surface. This makes air pollution not just a local problem, but a regional and a global one.

Shiliang Wu uses some well-established global models to examine the impacts of human activities on air quality, along with the complicated interactions between air quality, climate, land use, and land cover. Wu and his research team investigate a wide variety of pollutants including ozone, nitrogen oxides, volatile organic compounds, aerosols, mercury, and arsenic. "Essentially everything in the air, even the microbes—well, possibly one day," Wu says.

His team recently developed the first global model to simulate the sources, transport, and deposition of atmospheric arsenic including source-receptor relationships between various regions. They were motivated by a 2012 *Consumer Reports* magazine study, which tested more than 200 samples of rice products in the US and found that many of them, including some organic products and infant rice cereals, contained highly toxic arsenic at worrisome levels.

"Our model simulates arsenic concentrations in ambient air over many sites around the world," Wu explains. "We have shown that arsenic emissions from Asia and South America are the dominant sources of atmospheric arsenic in the Northern and Southern Hemispheres, respectively. Asian emissions are found to contribute nearly 40 percent of the total arsenic deposition over the Arctic and North America. Our results indicate that the reduction of anthropogenic arsenic emissions in Asia and South America could significantly reduce arsenic pollution not only locally but also globally."

The team's model simulation is not confined to any region or time period. "We can go back to the past or forward to the future; we can look at any place on Earth. As a matter of fact, some of my colleagues have applied the same models to Mars," Wu adds.

"In any case, the atmosphere is our lab, and we are interested in everything in the air."

Inspired by nature

Getting underwater robots to work together, continuously

Imagine deploying multiple undersea robots, all in touch and working together for months, even years, no matter how rigorous the mission, brutal the environment, or extreme the conditions.

It is possible, though not quite yet. "Limited energy resources and underwater communication are the biggest issues," says Nina Mahmoudian.

Grants from a National Science Foundation CAREER Award and the Young Investigator Program from the Office of Naval Research are helping Mahmoudian solve those issues and pursue her ultimate goal: the persistent operation of undersea robots.

"Autonomous underwater vehicles (AUVs) are becoming more affordable and accessible to the research community," she says. "But we still need multipurpose long-lasting AUVs that can adapt to new missions quickly and easily."

Mahmoudian has already developed a fleet of low-cost, underwater gliders, ROUGHIEs, to do just that. Powered by batteries, they move together through the water simply by adjusting their buoyancy and weight. Each one weighs about 25 pounds. "ROUGHIE, by the way, stands for Research-Oriented Underwater Glider for Hands-on Investigative Engineering," adds Mahmoudian.

"The ROUGHIE's open control architecture can be rapidly modified to incorporate new control algorithms and integrate novel sensors," she explains. "Components can be serviced, replaced, or rearranged in the field, so scientists can validate their research in situ." Research in underwater control systems, communication and networking, and cooperative planning and navigation all stand to gain.

Mahmoudian observes Mother Nature to design robotic systems. "There is so much to learn," she says. "My most exciting observation was a Beluga mother and calf swimming together. It's very similar to our recharge on-the-fly concept. The technology is an early stage of development."

Mahmoudian's students apply and implement their algorithms on real robots and test them in real environments. They also give back to the community, by teaching middle school students how to design, build, and program their own low-cost underwater robots using a simple water bottle, called a GUPPIE.

"As a girl growing up, I first thought of becoming an architect," says Mahmoudian. "Then, one day I visited an exhibition celebrating the 30th anniversary of space flight. That's when I found my passion."

Mahmoudian went on to pursue aerospace engineering in Iran, and then graduate studies at Virginia Tech in the Department of Aerospace and Ocean Engineering. "Underwater gliders share the same physical concepts as airplanes and gliders, but deal with different fluid density and interactions," she says.

Now at Michigan Tech, Mahmoudian's work advances the abilities of unmanned robotic systems in the air, on land, and under sea. "Michigan Tech has easy access to the North Woods and Lake Superior—an ideal surrogate environment for testing the kind of autonomous systems needed for long term, challenging expeditions, like Arctic system exploration, or searching for signs of life on Europa, Jupiter's moon."

More than scientists and engineers, Mahmoudian wants simple, low-cost AUV's to be available to anyone who may need one. She envisions communities in the Third World deploying AUVs to test and monitor the safety and quality of the water they use.

Nina Mahmoudian is director of the Nonlinear and Autonomous Systems Lab at Michigan Tech.





Heather Getty '84
Director of Research
& Development
Boston Scientific

A section of BSC's drug-eluting Eluvia stent system, designed to restore blood flow in the peripheral arteries above the knee.

Interventional devices

Improving quality of life

As an R&D director at Boston Scientific Corporation, Heather Getty works with a cross-functional team of experts to develop products and solutions for treating diseases using minimally invasive surgical techniques. The scope of these medical devices includes catheters, stents, and other devices for patients with peripheral artery disease, or PAD, a common circulatory problem in which narrowed arteries reduce blood flow to the limbs. PAD affects more than a quarter of a billion people worldwide. Patients with PAD can suffer significant health consequences, including gangrene, amputation, and triple the risk of heart attack and stroke. Boston Scientific is a market leader in less-invasive treatments for PAD.

"As a medical products company, we rely heavily on the experience and wisdom of the physicians who utilize our products," says Getty. "A big part of my job is understanding the treatment of PAD from the physician's perspective. We gain knowledge about customer needs by meeting with physicians, observing clinical cases, and having physicians use our products during development."

Product development can be extremely challenging. "Taking an idea, and moving it from concept to commercialization while navigating through technical challenges as well as financial and time constraints can be daunting," says Getty. "A product properly commercialized can stay in the market for over 30 years. Despite that realization and pressure, at the same time, it is also our job to recommend cancellation of any idea that can't meet expectations."

A critical part of her job is ensuring compliance with regulations across the globe. "We work very closely with our quality engineering department but it is also critical that everyone contributes to the quality and compliance of our products," she says.

Getty graduated from Michigan Tech with a bachelor's degree in Chemical Engineering, and immediately began working at Honeywell. While on the job she completed an MBA from St. Thomas University. After six years in manufacturing she moved into Honeywell's Material Test and Analysis (MTAC) group, and later began working on the development of demilitarization concepts, including exploring options to reclaim materials from ammunition dumps around the world. After 11 years, she leapt at the chance to join the R&D group at Schneider, now part of Boston Scientific, to follow her passion of improving lives.

Now, with more than 21 years total at Boston Scientific, Getty leads a team of 60 managers, engineers, and technicians who develop new products for the company. "It's rewarding to be with a company that offers opportunities to improve patient lives but that also manages to do so with integrity and a respect for work-life balance," Getty asserts. "Launching a product and having it do well in the market is another rewarding aspect of my work. I love that our products can help improve a person's quality of life as well as make a physician's job easier."

Long-range optics

Jeremy Bos

2017 AFOSR YIP Award

With his Young Investigator Program (YIP) grant, Jeremy Bos wants to help the Air Force see better.

Twinkling stars and mirages over hot roads are examples of atmospheric turbulence we see every day; the distortion comes from the way light interacts with shifting air. Sometimes turbulence causes the image to appear blurred. Other times it can be like looking at your reflection in rippling water.

When every pixel in an image has the same blurring function, the distortion is said to be isoplanatic. In the case of the rippling water, different parts of the image are distorted differently, or anisoplanatic. "In my work, I'm looking at the case where every single pixel in an image has a different blurring function," Bos says. He calls this "extreme anisoplanatism."



With his YIP award, Bos is piecing together images affected by anisoplanatism over long distances. Clearing up the noise from turbulence will provide information about the atmosphere as a three-dimensional space. "If I can characterize the atmosphere tomographically—like doctors do with CT scans—then I can use other techniques to back out the turbulence."

Bos is an assistant professor of electrical engineering.

Eco-friendly marine acoustics

Zhaohui Wang

2017 NSF CAREER Award

From monitoring whale populations to tactical surveillance, underwater acoustic communication networks are handy systems to have in place. But their greatest feature—being underwater—is also their greatest challenge.

Zhaohui Wang has a plan for improving underwater acoustics networks to maximize information delivery. The ambient soundscapes of the ocean floor, Lake Superior, or even small inland lakes are full of background noise, which can interfere with an acoustic signal—or a signal can interfere with natural sound, such as whale whistles. In addition, underwater environments change seasonally, daily or even hourly, which can alter a signal's



strength by the time it reaches the receiver.

With her NSF CAREER award, Wang will model, understand, and even predict underwater dynamics in real time. "One of my main goals is to develop a system that allows for harmonious co-existence with other acoustic systems—and marine animals." Wang is an assistant professor of electrical and computer engineering.

Biomimic batteries

Lucia Gauchia

2017 NSF CAREER Award

When batteries drain, people say they're dead. Recharging them is not the only way to bring them back to life. Lucia Gauchia studies what's called a battery's second life, when it is repurposed for a new use.

"In engineering, we take the fish out of the pond and expect to be able to tell how it's going to live in the pond; ecologists do not extract their subjects from their environment," she says. Gauchia instead turned to systems designs and population analyses that quantify individuals, groups and their interactions with their environment.

With her NSF CAREER award Gauchia will test a large number of batteries in first and second life stages under a variety of conditions—driving style, weather patterns, energy pricing, and others—taking into account where and how they are used. She will then use Bayesian net-



works to inform ecology-based methods to discern patterns in the data; with those patterns she can do cross-level testing to see what holds true from batteries to packs to modules. The analyses should help better predict when a battery might fail in any of its life stages.

"Batteries are interesting systems and they have peculiar behavior," she says. Gauchia is an assistant professor with a dual appointment in electrical engineering and mechanical engineering.



Anindya Majumdar, a doctoral student in biomedical engineering, uses scattered coherent light to view biophysical systems. Learn more at mtu.edu/unscripted



The green roof at Michigan Tech's Great Lakes Research Center minimizes rain runoff and helps cool the building in summer.

Office of the Dean

College of Engineering
Michigan Technological University
712 Minerals & Materials
Engineering Building
1400 Townsend Drive
Houghton, MI 49931-1295
Telephone: 906-487-2005
Fax: 906-487-2782
Email: engineering@mtu.edu
mtu.edu/engineering

Wayne D. Pennington
Dean

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Associate Dean for
Academic Affairs

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Boston Scientific

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Executive Vice President &
Chief Operating Officer ITC

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Business and Intellectual
Property Attorney and Partner
Knobloch & Tripp

Joe Nowosad
Manager, Steelmaking QA
& Laboratory Services,
Quality Assurance
ArcelorMittal

Ron Van Dell
President & CEO
ViZn Energy Systems, Inc.

Mike Whitens
Director, Global Body
Interior Engineering
Ford Motor Company



College of Engineering
Michigan Technological University
712 Minerals & Materials Engineering Building
1400 Townsend Drive
Houghton, MI 49931-1295

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